

Remarks:

This amendment is submitted in an earnest effort to advance this case to issue without delay.

The specification has been amended to eliminate some minor obvious errors, to place in the case the required PCT cross-reference paragraph, and to add standard US-style headings. No new matter whatsoever has been added.

The claims have been amended to eliminate the "preferable" recitations. Claim 1 has further been amended to be in better US form.

In addition claim 1 has been amended by insertion into it of subject matter found in the original application documents, that is in the originally filed translation, on page 4 in the middle of the page. Thus this claim now recites the process temperature of 268 to 274 °C prevailing in the reactor 2.

Finally the "free movement" recited in claim 1 has been defined more clearly by stating that it is "without stirring" to further clarify the claim.

There are several differences between the instant invention and the sole cited and applied reference, US patent 4,138,544 of Janssen.

1. In the instant invention the various trays or "ducts" of the reaction zones are fairly passive, except for the third and final reaction zone that has a stirrer 20. The process liquid is not stirred in upper zones whereas in Janssen stirrers are provided at every level, creating a fairly complex apparatus.

2. The reactor 2 of the instant invention is maintained at a uniform treatment temperature between 268 °C and 247 °C. In Janssen the temperature as described in example 1 is stepped from 140 °C to 225 °C. Thus Janssen not only teaches the use of a varying temperature, but one that is wholly outside the claimed range.

3. In the instant invention the entire reactor is maintained under a subatmospheric pressure, defined as a fraction of the diol equilibrium pressure. In Janssen the first five trays are under atmospheric pressure.


In general the instant invention uses a much simpler system than Janssen, who has 30 reaction chambers (column 5, line 6). This is possible because of the higher claimed temperature used according to the invention for the prepolycondensation of ethylene glycol with terephthalic acid as compared to the lower temperature used by Janssen for less stable and more fragile polyesters containing butandiol-1,4. Such gentle reaction conditions are required in Janssen as shown in example 7 f using ethylene glycole to get a precondensate at a viscosity of 0.10 to 0.11 dl/g that is considerably lower than the viscosity in the examples where butandiol-1,4 is used. This low viscosity makes the process much less advantageous.

Hence it is clear that the process and apparatus of Janssen cannot be considered as a model for making of other polyesters that have to be made in high reduced viscosities and in large amounts.

For the reasons advance above, all the claims in the case are clearly allowable under §102 and §103 over the cited art. Allowance of all claims and passage to issue are in order.

If only minor problems that could be corrected by means of a telephone conference stand in the way of allowance of this case, the examiner is invited to call the undersigned to make the necessary corrections.

Respectfully submitted,  
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Enclosure: Request for extension (one month)  
Corrected version of translation  
Substitute Specification

## METHOD AND DEVICE FOR THE CONTINUOUS PRODUCTION OF POLYESTERS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is the US national phase of PCT application PCT/EP2003/010444, filed 19 September 2003, published 22 April 2004 as WO 2004/033526, and claiming the priority of German patent application 10246251.8 itself filed 2 October 2002.

FIELD OF THE INVENTION

This invention relates to a process and an apparatus for the continuous production of polyesters (PES) by esterification/transesterification of dicarboxylic acids or dicarboxylic acid esters with diols, preferably polyethylene terephthalate (PET), proceeding from terephthalic acid (PTA) or dimethyl terephthalate (DMT) and ethylene glycol (EG), in at least one reaction stage, prepolycondensation of the esterification/transesterification product under a vacuum by means of a reaction stage consisting of a vertical reactor, and polycondensation of the prepolycondensation product in at least one polycondensation stage.

BACKGROUND OF THE INVENTION

For the continuous production of PET, PTA or dimethyl terephthalate (DMT) and EG are used as starting substances. PTA is mixed with EG and a catalyst solution to form a paste and charged to a first reaction stage for esterification, in which esterification is effected at atmospheric or superatmospheric pressure by separating water. When DMT is used, the DMT melt and the catalyst together with the EG are supplied to a first reaction

stage for transesterification, in which the reaction is effected at atmospheric pressure by separating methanol (MeOH). The product stream of the esterification/transesterification is supplied to a reaction stage for prepolycondensation, which generally is performed under a vacuum. The product stream from the prepolycondensation is introduced into a reaction stage for polycondensation. The polyester melt obtained is directly processed to obtain fibers or chips.

The conventional process for producing PET comprises two stirring stages each for esterification and prepolycondensation and a horizontal cascade reactor for polycondensation, which includes bottom chambers and a stirrer equipped with vertical perforated or ring disks on a horizontal shaft for the purpose of producing a defined surface. The disadvantages of this process must in particular be seen in that inside the cascade reactor comparatively high temperatures of 284 to 288° C., which are disadvantageous for the quality, occur with sufficiently large flow rates. The vacuum applied in the first stirring stage of the prepolycondensation to avoid foaming and entrainment of droplets is limited to  $p \geq 50$  mbar. The viscosity of the prepolycondensation product likewise is limited to a range of 0.20 to 0.24 IV. What is furthermore disadvantageous is the increased gas yield in the cascade reactor forming the polycondensation stage. The use of a horizontal cascade reactor instead of the second stirring stage for prepolycondensation allows a high flexibility of the PET production with comparatively lower temperatures of 277 to 283° C in the cascade reactor for polycondensation and an increased viscosity of

the prepolycondensation product of 0.27 to 0.31 IV as well as optimum possibilities for increasing the plant capacity (Schumann, Heinz-Dieter: Polyester producing plants: principles and technology. Landsberg/Lech: Verlag Modeme Industrie, 1996, pp. 27 to 33). What remains disadvantageous, however, are the high investment costs for the apparatus involved and the company building.

In a plant comprising two stirred tanks for esterification, a storey-type multilevel reactor for prepolycondensation and a horizontal cascade reactor for polycondensation, a comparable stability and flexibility of the polyester production is obtained with relatively little effort, but with the disadvantage that the dimensions of the reactors of the prepolycondensation and polycondensation stages will be increased because of increased vapor volumes, and the admissible transport dimensions are reached already with mean plant capacities.

In the process of producing PET by means of four reaction stages, which is described in DE-C-4415220, a vertical reactor is used each for postesterification and prepolycondensation. In its initial upper region, the reactor has a helical duct with product inlet at the wall, which is open at the top and, extending from the outside to the inside, communicates via a central overflow with a stirred product sump disposed at the bottom, the duct bottom ascending continuously in flow direction, so that the depth of the product stream is decreasing continuously. Heating the product stream is effected by means of individual radiators initially repeated at intervals and optionally via the duct walls. By means

of the duct bottom ascending in flow direction an automatic system evacuation in flow direction is prevented with the consequence of the formation of residues, quality deterioration or product losses, in particular in the case of operating troubles or when shutting  
5 down the production plant. Due to the evaporation surface limited by a single duct bottom, the operating vacuum is either restricted, the operating temperature is increased, the color quality of the product produced is decreased, or an increased vacuum involves the risk of an excessive vapor velocity and an entrainment of droplets  
10 critical for a trouble-free condensation; this effect is intensified in addition by locally concentrated radiators in the flow duct.

U.S. Pat. No. 5,464,590 discloses a vertical polymerization reactor with a plurality of trays disposed  
15 vertically one above the other, which each have two flow ducts open at the top at the respective duct end, and an overflow weir with adjoining bottom recess for the vertical transfer of product in the form of a freely falling film on the succeeding tray. The duct has the shape of an approximately ring-shaped double loop, the  
20 respective first loop semicircularly being deflected into the second opposed loop. The liquid polymer traverses the ducts from the top to the bottom in a free movement. The vapors each flow between the trays towards the middle of the reactor and escape via central tray apertures to the vapor outlet at the reactor lid. A  
25 low filling level on the trays and a heating restricted to the bottom region involve a dwell time deficit for the prepolycondensation of esterification products with restricted

polymer degrees of 4.5 to 7.5 with the consequence that either the number of trays or the dimensions of the reactor must be increased. Another disadvantage must be seen in that reaction space is lost due to the incorporation of guides and free falling-film zones. Due to the horizontal arrangement of the duct bottoms and due to the overflow weirs, a residue-free continuous operation of the reactor and/or its complete drainability are not ensured.

The same disadvantages are also obtained with the polymerization reactor represented in U.S. Pat. No. 5,466,419, in which the product charged to the first ring duct is divided in two partial streams, which each traverse two semicircular loops and half a distance up to the flow reversal and the overflow weir or the product outlet, i.e. with a comparable duct cross-section the flow velocity likewise is halved and the hydrostatic pressure difference is reduced.

#### OBJECT OF THE INVENTION

It is the object of the present invention to perform the prepolycondensation in the above-described process for producing PES in a reaction stage and at the same time increase the viscosity of the prepolycondensation product to 0.24 to 0.26 IV at a lower process temperatures of 268 to 275° C in the prepolycondensation stage and 276 to 282° C in the polycondensation stage as well as a lower vacuum of 7 to 18 mbar. Furthermore, foaming and entrainment of droplets should be easy to control.

#### SUMMARY OF THE INVENTION

This object is solved in that the esterification/transesterification product flowing into the



reactor, in which there exists a pressure of 10 to 40% of the diol equilibrium pressure of the prepolycondensation product leaving the reactor, successively traverses with a constant product height in a free movement under limited heating first at least one first  
5 reaction zone formed of a channel, then is introduced into the radially outer or radially inner ring duct of at least one second reaction zone formed of an annular channel divided into a plurality of concentric ring ducts, and with a constant product height is successively passed through the ring ducts to the outlet and then  
10 into a stirred third reaction zone located at the bottom of the reactor. Due to the arrangement of a first and a second reaction zone, a sufficiently large evaporation surface and hence a restriction of the vapor load is achieved.

The total pressure of the reaction product at the bottom  
15 of the channels of the first and second reaction zones, which results from the hydrostatic pressure and the operating pressure, is smaller than the local diol equilibrium pressure of the polycondensation stage and is about 5 to 80%, preferably about 10 to 70% of the diol equilibrium pressure. As a result, reproducible  
20 polycondensation conditions can be achieved in a relatively simple way. For the EG equilibrium pressure the following applies:  $p_{OL} = 4p_{s,T}[(DP)^2 - 1]^{-1}$ , where  $p_{s,T}$  designates the EG- vapor pressure and DP designates the degree of polymerization.

At comparable relative total pressures, the product  
25 height in the ring ducts of the second reaction zone is lower than the product height in the channel of the first reaction zone by the factor of 2 to 3.5.

Usually, the vapors formed in the three reaction zones are jointly withdrawn from the reactor. A preferred aspect of the invention consists in that the vapors of the first reaction zone are supplied to a separator for the entrained product droplets, before the same are combined with the vapors of the two other reaction zones. By means of this measure the foam and droplet problem can be controlled.

The flow in the channel forming the first reaction zone can be regarded as turbulent because of the vigorous generation of gas up to about half the flow path. With decreasing generation of gas and increasing viscosity of the product stream a laminar flow will be obtained in the last third of the flow path at the latest. According to the principle of the similarity of flows in open conduits, the flow of the product stream in the ring ducts of the second reaction zone is a laminar flow. To avoid the formation of a faster core flow and a slower edge flow at the bottom and at the walls of the channel of the first reaction zone as well as in the ring ducts of the second reaction zone in the case of a laminar flow, it is necessary in accordance with another feature of the invention to slow down the velocity of the core flow and to accelerate the velocity of the edge flow.

In accordance with the further aspect of the invention, the product stream is passed concurrently parallel or countercurrently parallel through the ring ducts of the second reaction stage.

In the apparatus for performing the process, a heating register extending in flow direction is arranged in the channel of

the first reaction zone for the limited controlled heating of the product stream, the tubes of which heating register are retained in chamber sheets mounted transverse to the flow direction with a bottom-free and/or wall-free passage. By means of these chamber sheets the axial velocity of the product stream is slowed down in the free edge zones and relatively accelerated in the vicinity of the heating register and at the bottom. Conversely, by means of flow installations in the succeeding laminar conduit flows the slower velocity at the edge and at the bottom is accelerated and decelerated in the faster core flow.

In accordance with the particular aspect of the apparatus, a closed vapor collecting space is provided above the channel of the first reaction zone, whose outlet opening is connected with a separator, preferably including a cyclone-like gas conduit, for the entrained product droplets.

To achieve a constancy of the product levels in the channel of the first reaction zone and in the ring ducts of the second reaction zone, overflow baffle plates or overflow tubes are mounted at the end of the channels or ring ducts in accordance with an additional feature of the invention, and expediently an underflow baffle plate should be provided upstream of each overflow baffle plate and a riser should be provided upstream of each overflow tube, in order to avoid separation effects or residues.

[0018] To provide for an automatic and complete, i.e. residue-free evacuation of the channel of the first reaction zone and of the ring ducts of the second reaction zone of the reactor when shutting off the apparatus for producing PES, the arrangement of a gooseneck

outlet at the deepest point of the bottom is provided at the end thereof among several possible concepts in accordance with another feature of the invention.

In accordance with another feature of the invention a drainage tube or interposed drainage openings are additionally arranged at the ends of channel and/or ring ducts in the rearmost dead corner at the deepest point of the bottom, in order to avoid an accumulation of residues.

Expediently, the bottom of the channel of the first reaction zone and/or that of the channel forming the ring ducts of the second reaction zone is inclined at an angle of 0.5 to 6°, preferably 1 to 4° with respect to the horizontal plane.

One aspect of the apparatus consists in that the stirrer for the third reaction zone is a ground-running impeller, a finger, frame or drum stirrer, each with a vertical drive axle.

Alternatively, the stirrer for the third reaction zone can be part of a rotary-disk cascade or a cage reactor, each with a horizontal drive axle. The rotary-disk cascade includes perforated, ring or solid disks, the inlet for the reaction product being half mounted at each of the axial ends and the common outlet being mounted in the middle. In the case of a rotary-disk cascade with perforated disks, it is also possible to arrange the inlet for the reaction product at the one end and to arrange the outlet at the opposite end.

#### BRIEF DESCRIPTION OF THE DRAWING

The invention is represented shown in the drawing by way of example and will be explained below. The sole figure of the

drawing is a partly schematic vertical section through an apparatus for carrying out the method of this invention.

#### SPECIFIC DESCRIPTION

As ~~[[is]]~~ shown in the longitudinal ~~section drawing~~, an esterification product for prepolycondensation is supplied via a conduit 1 to ~~[[the]]~~ a vertical reaction vessel 2 into ~~[[the]]~~ a radially extending channel or trough 3 which is arranged therein and forms the first reaction zone. In the channel 3 ~~[[,]]~~ there is a heating register 4 ~~is located~~, whose having tubes 5 ~~[[are]]~~ arranged concentrically. For forming a vapor-collecting space 6, the channel 3 ~~is terminated~~ extended at the top by a wall 7 extending concentrically between the radial outer channel wall and the reaction vessel 2. ~~[[The]]~~ Product droplets entrained from the vapor-collecting space 6 are separated in ~~[[the]]~~ a cyclone-like separator 8. The product leaving the channel 3 ~~is charged~~ flows via an overflow tube 9 ~~at the beginning to an outside edge~~ of an external ring duct 10 and thereafter ~~a channel including~~ and then flows through two further ring ducts 11, 12 ~~[[and]]~~ forming with the duct 10 the first portion 13 of the second reaction zone. Upon traversing the ring ducts 10, 11, 12, the product ~~is discharged~~ flows through an overflow tube 14 at the end of the ~~internal innermost~~ ring duct 12 ~~and is introduced~~ into the external ring duct 15 of a channel including two further ring ducts 16, 17 and forming the second portion 18 of the second reaction zone. At the end of the ~~internal~~ innermost ring duct 17, the product is ~~discharged~~ flows via the overflow tube 19 ~~and supplied~~ to the sump 22 forming the third reaction zone at the bottom of the vessel 2

and is stirred by means of an impeller 20 with a vertical drive axle 21. The vapors obtained in the three reaction zones ~~[[are]]~~ pass ~~[[ed]]~~ to the outside via a conduit 23. The prepolycondensation product is discharged from the sump 22 via a conduit 24 and supplied to ~~the non-~~ an unillustrated polycondensation stage.